Chapter 1

Introduction
The Problem and Its Setting:
Geographic Information Systems In Secondary Education:
Promise and Reality

Context of the Research Problem

Technology and Educational Reform

“Classrooms in Crisis” proclaimed the headlines of *The Denver Post* –“Drastic reforms needed to save our education system” (Melcher 1999). Vice-President Gore argued for “revolutionary change in America’s schools” (*The Denver Post* 1999). These were not isolated commentaries. Throughout the 1990s, educational reform received great attention from the media, while the President and school district superintendents alike claimed it as one of their top priorities. Public concern about the quality of teaching and learning has risen alongside rapid economic, technological, and political changes. Charter schools, vouchers, national and local content standards, school violence, and test scores are issues raised in the reform movement. The rapid expansion of technology in society also found voice in these educational debates, revolving around what schools should teach with the computer, and about the computer. Educational technology is perceived as a major vehicle in the movement toward education reform (Plotnick 1995; Trotter 1997). Workers will be increasingly expected to demonstrate knowledge and skills that will make them successful in the information age (Scott 1999).

Coincident with these events is increasing recognition that geography education is important to society as a whole. The report *Rediscovering Geography* (National Research Council 1997) argued that education reform is essential if geography education is to benefit society:

> “[There] is a well-documented growing perception (external to geography as a discipline) that geography is useful, perhaps even necessary, in meeting societal needs. As a result, many parties…have been asking more from the information, techniques, and perspectives associated with geography than the nation’s scientific and educational systems are delivering; and the gap between demand and supply may be widening. The most salient aspect of this demand is in education reform, especially in grades K-12” (p. ix).

The Geographic Education Renaissance and Reformation

Once a neglected discipline, buried in the social studies, geography is experiencing a resurgence at all levels of education in the United States. Geographic skills are increasingly viewed as relevant and essential for well-informed citizens to function in today’s changing world. Geography education that explores real-world issues is increasingly viewed as having potential for making a significant contribution to politics, research, and business. The renaissance of geography teaching and learning includes an expanded presence at all levels of education, evidenced by increased numbers of teacher training programs, state geography curriculum frameworks, a set of national standards, conferences, courses, curricular materials, and lesson modules. No longer memorized as a series of rote facts about the location and characteristics of places, geography is increasingly explored as both a social and physical science that examines the relationship of humans to their environment. Thus, geography is not only experiencing a renaissance, but also a reformation.

The Advent and Expansion of Geographic Information Systems

Concurrent with calls for educational reform and the resurgence of geography education is tremendous expansion in the application of geographic information systems (GIS). GIS consists of a set of hardware, software, data about places on the earth, and an inquisitive human investigator who inquires about and explores the world via the computer. A GIS contains a set of tools that allow geographic data to be stored, accessed, and analyzed. The visual elements used in these analyses, essential media of exploration and communication, exploit the human need for maps and graphics to convey large amounts of information. The concepts of spatial association and analysis foreshadowed GIS, and found increasing voice in GIS technology. Since the mid-1960s, GIS has enabled users to create not only their own maps, but also to visualize and analyze complex interrelationships among a variety of phenomena. Because so many problems that humans face are spatial in nature, GIS has been successfully used to solve those problems. For example, spatial information about soils and urban development is input to a GIS model of soil liquefaction potential to assess risk to structures in the event of an earthquake.

Spatial Data and Analysis

Data for GIS, or *spatial* data, are usually organized into layers or themes about the earth, such as transportation, soils, hydrography, elevation, climate, or population. These themes may be comprised of vector information—points, lines, and areas—or raster information—scanned maps, aerial photographs, or satellite imagery. Connected to each layer of spatial information is tabular information containing attributes of the specific theme. For example, a stream *line* might contain attributes about the direction of flow and the stream name; a water well *point* might contain information about depth to water surface, pH, and dissolved solids; a census tract *area* might contain demographic information; and a satellite *image* may contain information about the spectral reflectance values across bands of electromagnetic energy to which the satellite's sensor is sensitive. Each theme is registered in geographic space, allowing the operator to superimpose them on a display. Within each theme is topological integrity—the features "know" how they are connected to other features. For example, each line segment in the stream network is connected in a specific way to the other *lines*, divided by beginning and ending *points*, and bounded on the left and right by *areas*, or polygons. The operator of the geographic information system then can pose *queries,* or questions about the spatial and attribute information in one or more themes in order to model, predict, and make decisions about the phenomenon applied to a real-world problem. The final step is the generation of maps, charts, tables, web pages, animations, and other graphical, multimedia forms of communication.

GIS analysis has been a critical part of land-based decisions made daily by academic, business, and government organizations for over 20 years. GIS is used routinely by such organizations as utility companies to plan and maintain gas and electric facilities, by wildlife biologists to assess animal habitat, by retailers seeking to establish the best location for a new fast-food restaurant, and by epidemiologists to track the diffusion of diseases. GIS has become a $5 billion business worldwide (Phoenix 1999) and has been growing by over 10% annually for the past decade (GeoPlace Incorporated 1998). Over 500,000 people worldwide use GIS software (Phoenix 1999). The GIS industry encompasses software and hardware developers, research, sales, data producers and consumers, consultants, professional societies, journals, user groups, and conferences. One GIS conference alone, that hosted by the Environmental Systems Research Institute, attracts 10,000 people annually. A maturation of issues surrounding spatial analysis, societal effects, data management, quality, and integration in GIS, digital cartography, remote sensing, and global positioning systems have prompted many to suggest that a new discipline of *geographic information science* has emerged (Goodchild 1992).

Geography Education and GIS: Progress and Needs

GIS is not the only method of making maps and examining geographic data on the computer. Beginning in the 1980s, *PC-GLOBE* software paved the way for other comprehensive atlases on CD-ROM: *Cartopedia* (DK Multimedia), *Encarta Virtual Globe* (Microsoft), *World Almanacs* (Mindscape), and *New Millennium* (Rand McNally). *Interactive Earth* (Forest Technologies) contains 250 world maps and 350 audio narrations, movies, and animations. GeoHistory makes a CD containing maps of ancient civilizations and Houghton Mifflin's *Rescue Geo* CD includes 600 questions and 1,400 maps, charts, and photographs to help students learn about the United States. Pierian Spring and World Construction Set software allow the student to create three-dimensional landscapes. Students can use *NGS Works* (National Geographic Society) to exchange information via email, collect and graph data, and plot data points on maps. During 1999, Internet map server technology spread to hundreds of sites, allowing users to create custom maps using real geospatial data using a simple browser to the World Wide Web. However, all of these media stop short of the analytical capabilities possible with a GIS. Users can create maps with an infinite variety of themes and scales with a GIS, but in addition, can analyze the relationships of features and their attributes across space and time.

The above mapmaking media are given frequent attention in teaching catalogs and educational journals such as *Media and Methods* (see Johnson 1998), yet GIS is curiously absent. GIS is also absent from or given minimal treatment in texts created to help teachers evaluate educational technology such as CD-ROMs, videodiscs, presentation programs, and telecommunication (such as Barron and Orwig 1997). Given the exposure of non-GIS educational software and its increasing capabilities, what motivates teachers to use GIS software instead of non-GIS software? What discourages others from using GIS? Research is needed to determine whether GIS truly offers enhanced learning over non-GIS tools, and to identify those factors that teachers use in their implementation decisions. This research must examine whether the use of GIS requires a different teaching method. If GIS does offer enhanced learning and a different teaching method, the research must analyze whether teachers consider and are equipped to deal with the pedagogical ramifications of using GIS.

The use of geographic information systems (GIS) technology and methods has the potential to incorporate issues-based and inquiry-oriented education, and to increase the relevancy and utility of the disciplines in which they are used. GIS "can be an integral part of the spatial analysis tradition, as it enhances the ability to recognize, interpret, describe, and measure spatial relationships" (Nellis 1994). Conducting spatial analysis within and across themes of information to arrive at a decision has been taught using manual overlay techniques and traditional materials, but the available media limited the complexity of the problems analyzed. It is simply not feasible without a GIS, for example, for students to examine the location of every earthquake epicenter across the globe for an entire year, and determine the pattern of these epicenters related to plate boundaries, cities, and fault lines. Geographic information systems "make the process of presenting and analyzing geographic information easier, so they accelerate geographic inquiry≅ claimed the creators of the national geography content standards (Geography Education Standards Project

1994: 45). An increasing number of educators consider GIS to be one of the most promising means for implementing educational reform, by using teams of students who construct their own analyses and geographic representations of real-world data (Ramirez 1995).

Scholars have long advocated that the bulk of GIS instruction should reside in the discipline of geography. Mark and Dickenson (1991) linked GIS use with Pattison's (1964) four traditions of geography—spatial analysis, characterizing regions, demonstrating human-environment interaction, and modeling earth science processes. Nellis (1994) showed that GIS can illustrate the five core themes of geography—location, place, human-environment interaction, movement, and region. GIS has been shown as enabling technology for science, as an intellectual theme of geography, a tool to support geographic inquiry, and a collection of marketable skills (Abler 1988; Kemp, Goodchild, and Dodson 1992; Morrison 1991). However, these advocates emphasize college-level teaching, rather than high school. In addition, they focus on teaching *about* GIS, rather than *with* GIS.

The curricular and geographic extent of GIS in secondary education is unknown. The factors that influence the diffusion of GIS across the country and within an individual school need to be examined.

Furthermore, empirical evidence is necessary to establish whether GIS tools are what they are claimed to beXwhether GIS can enhance the acquisition of geographic skills and knowledge. Research is needed to understand whether GIS can enhance critical thinking skills, and the educational settings and teaching styles in which GIS can be effective. Qualitative and quantitative assessments of GIS-based lesson modules are necessary to understand the effect of the technologies on the geographic knowledge of secondary school geography students. Evidence that would lead to a more effective use of GIS technology to teach geography is thus far largely nonexistent.

Researchers have examined gender differences in computer-based learning (Chapman 1997; Kirova-Petrova et al. 1999), in geography (Beatty et al. 1987; Cline 1984; Henrie et al. 1997; Montello et al. 1999; and Nairn 1991), and in geographic technology (Forsyth 1989). Findings suggest that when females and males have had the same amounts and types of experiences on computers, achievement scores are similar (Kirkpatrick and Cuban 1998). However, females and males differ in terms of when, where, and how they use computers, leading to an underrepresentation of females in computer sciences and a difference in achievement. It is unknown whether a gender difference in learning with GIS exists. Many have voiced concerns about the possibility that computers promote general inequity within the classroom and among schools, due to learning differences and socioeconomic status (Kirby et al. 1990). It is unknown whether GIS promotes or reduces this inequity.

Educators need research that results in lesson modules that they can use in their curricula, and data about the difference that GIS makes in teaching and learning. Unless an examination is conducted of how GIS lesson modules can be developed and tested, progress toward true assessment of GIS cannot be made. Teachers lack the time that is necessary to simultaneously learn complicated software and create GIS-based lessons. Thus, research needs to include a practical component of developing and testing modules that teachers could implement in their own classrooms. Teachers will be able to use the evidence and lesson modules developed through this dissertation to understand the potential of GIS for transforming geography teaching and learning.

Since the publication of the first national content standards in geography (Geography Education Standards Project 1994), social studies (National Council for the Social Studies, National Task Force for Social Studies Standards 1994), science (National Research Council 1996), and technology (International Society for Technology in Education 2000), educators nationwide have been progressing toward a model of “inquiry-based” instruction that emphasizes a hands-on, research-based learning experience. Inquiry draws upon learning theory referred to as constructivism, which holds that rather than being transferred from teacher to student, knowledge is *constructed* by the learner based on his or her own experiences (Driver et al. 1994). Students using the inquiry approach must form research questions, develop a methodology, gather and analyze data, and draw conclusions. However, many teachers and students are not comfortable with the pedagogical shift required for scientific investigation or the tools to support such investigation. GIS may provide the tool and the methods to change current practice to implement content standards. Furthermore, throughout the standards, technology is emphasized as a skill embedded in each discipline, rather than a stand-alone, separate subject or tool.

Hence, GIS is simultaneously a discipline with its own research agenda, a tool for research in many disciplines, and, most importantly for this study, a tool for education. During the 1980s, GIS rapidly diffused into the university curricula, to the point where nearly every geography department, as well as many science, engineering, and business departments, offer introductory and advanced GIS courses. During the 1990s, a similar rapid diffusion took place at the community college level.

Despite the global advance of GIS technology and methods in business, government, and academia, and despite claims that its application in secondary education would bring systemic reform, GIS has been adopted by only an estimated 1% of American high schools. With the exception of a study by Audet and Paris

(1997), the reasons for this slow adoption rate in secondary education have not systematically been examined prior to this dissertation.

Therefore, an examination of the relevant theoretical and practical issues associated with implementing and assessing GIS in secondary geography is needed. This dissertation examines GIS education both nationally and in specific classrooms. Through these methods, national trends, catalysts, and challenges to implementation and effectiveness can be discovered. An in-depth examination of classrooms where GIS has been implemented can reveal its effectiveness and uncover practical issues involved in its implementation.

The Research Problem

This research *describes, explains, and assesses* the implementation of GIS technology and methods in secondary education in the United States. The study addresses the relevant technological, methodological, instructional, sociological, and behavioral issues surrounding the implementation of GIS technology and methods to teach secondary geography. The study examines *why* and *how* GIS is implemented in secondary education in the United States. The study investigates *how* and *to what extent* inquiry-oriented GIS lesson modules affect the knowledge of standards-based geographic content of selected secondary school geography students.

Research Subproblems

The research is organized to address three subproblems in order to: (1) describe the extent to which GIS technology and methods are being implemented in secondary education in the United States, including the specific disciplines, extent in the curriculum, and the spatial and temporal pattern of adoption; (2) explain why and how GIS technology and methods are being implemented in secondary education, analyzing technological, methodological, instructional, sociological, and behavioral barriers and catalysts; and (3) develop GIS-based lesson modules and assess how and to what extent these modules affect the acquisition of standards-based geographic content and skills of selected secondary geography students.

Hypotheses

This study poses nine hypotheses. First, social, educational, and political factors are more important influences on implementing GIS technology in the secondary curriculum than technological factors. Second, implementing GIS tools in high-school curricula fundamentally alters the manner of teaching in the classroom. Third, implementing GIS tools in high-school curricula fundamentally alters the manner of learning in the classroom. Fourth, instructional methods that teachers use with GIS are more closely aligned with the key tenets of modern educational reform than methods the teachers used before the introduction of the technology. Fifth, the introduction of inquiry-oriented lesson modules that use GIS tools and methods will increase the content knowledge and geographic skills as measured by national geography standards of selected secondary-school geography students to a greater extent than will the same lesson modules that do not include GIS. Sixth, female students using GIS will demonstrate a greater increase in skills over the course of a semester than will male students using the same technology and lessons. This is because female students more often demonstrate a lower level of initial computer skills than male students. Seventh, the use of GIS strengthens inquiry-oriented, problem-solving skills, rather than traditional locational geographic knowledge. Eighth, GIS technology and methods are implemented in the secondary curriculum primarily through the efforts of individual teachers, rather than via a systematic, national educational agenda. Lastly, a greater amount of professional development and contact with the local community is associated with teachers using GIS than with teachers who do not use GIS.

Assumptions

This study makes seven assumptions. First, augmenting geography skills and knowledge of secondary school students is needed. In order to be able to make well-informed decisions as adults, it is critical for all students to develop geographic skills and understand geographic concepts. Second, the national geography standards are valid criteria by which to assess the understanding of geographic content and the acquisition of geographic skills by secondary-school geography students. Third, geographic skills of secondary students as measured by the national geography standards can be objectively assessed by the administration of a series of pre-tests and post-tests. Fourth, teachers selected for the national portion of this study responded to the survey questionnaire in an unbiased and competent manner. Fifth, teachers selected for the case study and experimental portion of this study answered questions in the interviews, taught the lesson modules, and administered the assessments in an unbiased and competent manner. Sixth, students selected for the case study and experimental portion of this study answered oral and written questions in an unbiased and competent manner. Seventh, the author did not bias the results of the experiments and case studies in the manner in which he assessed tests and assignments, or by his presence in the classrooms under study.

Limitations of the Study

This study did not evaluate the effectiveness of the national geography standards. It used the standards as a framework upon which to build lesson modules and to assess student performance. The survey of secondary schools using GIS included Grades 9 through 12 in the United States only—students primarily aged 14 to 18 years. This study surveyed only those who owned one of three selected GIS software packages—*ArcView* (Environmental Systems Research Institute, Inc.), *Idrisi* (Clark University), and *MapInfo* (MapInfo Corporation). This study did not attempt to compare the teaching effectiveness of geography instructors. The experimental and case study portion of this research was limited to selected geography classes in three high schools in Colorado. The process of evaluating student performance did not measure developmental differences of the population studied, nor externalities such as the students' socioeconomic background, prior experience with the computers or with geography, or interest in the subject.

The Significance Of and Need For the Study

GIS Potential versus Practice

Maps are essential tools of exploration and communication. They exploit the human partiality for visuals and graphics to help convey large amounts of spatial information. Over the past 25 years, GIS has enabled users to not only create their own maps, but also allowed them to visualize and analyze complex interrelationships among spatial data sets. Because most data that humans work with and problems that they face are spatial in nature, GIS has been applied to decision-making that has made the results more efficient, interdisciplinary, and prudent. GIS is practiced in nearly all major disciplines, including geography, biology, meteorology, zoology, business marketing and management, botany, economics, archaeology, geology, planning, political science, sociology, and engineering. GIS can be used to analyze phenomena, process, and behavior across time and space, across scales from local to global. This can be accomplished using the map, animation, image, chart, graph, spreadsheet, and statistics tools within a GIS.

Despite the fact that many teachers perceive the implementation of GIS to be advantageous, a wide gulf remains between these capabilities of GIS and its actual practice in education. Every new educational technology has promised improved motivation, instruction, and learning, making teachers wary of technology-driven change. Because of this, Bednarz advised that "in order to continue the diffusion of GIS, a justification for using it to teach geography is needed" (1995: 45). This dissertation examines why educators are interested in GIS, and what they are doing with it. It examines factors that are critical in determining the success or failure of implementing this technology in the high school curriculum.

University researchers (for example, Marble 1999) link inadequate GIS education to restricted research and societal benefits:

> "Existing GIS education generally fails to provide the background in geographic information science (GIScience) that is necessary to meet the needs either of the users of GIScience technology or of the scientific community. […] Students [are] introduced only to the operational aspects of existing software systems. In far too many cases, the problem is one of both breadth and depth (p.1)."

Investigating GIS in secondary education can provide a starting point to meet the goal of improving society's ability to perform spatial analysis.

Assessing Standards-Based, GIS-Based Lessons

Researchers at the First National Conference on the Educational Applications of GIS (Barstow et al. 1994) and other GIS implementation researchers (Winn 1997; Thompson 1987) have recommended that development projects be established in order to create exemplary GIS-based curriculum materials in a range of subject areas and grade levels.

This dissertation provides a set of workable lessons that will begin to close the gulf between GIS capability and practice. These lessons, developed in the context of action research, are designed to bring about change as a direct result of the research process (Fien and Hillcoat 1996) because they may be refined and reused. These lessons can contribute to the growing library of resources to improve geography education, and form a portion of the Virtual Geography Department curriculum materials on the World Wide Web, a project funded by the National Science Foundation (Foote 1998).

The publication of the national geography standards created a critical need to determine the effectiveness of *standards-based* lesson modules. Standards are intended to ensure appropriate academic content for all grade levels, encourage high expectations for performance from all students, foster an educational system focused on common, well-defined goals, and build upon the best educational practice found in classrooms. Standards provide accountability throughout the education system. The emphasis underlying the national geography standards is to make students into accountable, active learners who will compete against these standards rather than against each other. Because this dissertation illustrates several methods of assessing the effectiveness of standards-based lesson modules, it takes one of the first steps in determining if GIS can be effectively merged with the national geography standards. This can inform policymakers who are modifying national standards for their states and school districts, as well as teachers who can apply these assessment measures in their own classrooms.

Examining the decision-making process essential for teachers to effectively implement a GIS, instruct students, and train other teachers will strengthen future training programs. By providing lesson modules, this dissertation may contribute a greater awareness of the potential of GIS in geography and other disciplines, and may offer starting points for further exploration.

Connecting GIS to Tenets of Educational Reform

"If restructuring is to succeed on a large scale, it will need to take maximum advantage of the tools and techniques that can support the process," claimed Sheingold (1991). This dissertation examines whether GIS is suitable as one of the tools to foster educational reform.

Interdisciplinary education is receiving increasing attention (Schrum 1999). Studies show that interdisciplinary education, rather than teaching each subject in isolation from the others, is a more effective means to help students solve problems (Jacobs 1989). The proper study of geography requires students to integrate earth science, history, economics, language arts, and mathematics. Implementing GIS into the curriculum may encourage students to examine data from a variety of fields (Furner and Ramirez 1999; Sarnoff 2000), but the utility of this approach has not been evaluated.

Developing problem-solving skills is also receiving increased emphasis in education (Barell 1998; Fogarty 1998). To equip them to solve problems on the job, students are given tasks that are similar to those faced in the day-to-day workplace—problems that require multidisciplinary approaches using data in a variety of formats. Providing students with better analytical, interdisciplinary skills while still in high school has the potential to cause changes in future undergraduate curricula, replacing the need for some introductory courses with more advanced courses dealing with real issues in each discipline.

The unprecedented attention to geography education at all levels over the past decade may be strengthened and extended with the aid of properly-applied GIS technology. The U.S. Secretary of Labor=s Commission on Achieving Necessary Skills (SCANS) stated that the most effective way to teach skills is Ain context≅ (U.S. Department of Labor 1991). This means learning content while solving realistic problems, often in groups, where students are active learners. The SCANS competencies recommended by the U.S. Department of Labor include identifying and using resources, working with others, acquiring and using information, and understanding complex interrelationships. Hill (1995a and 1995b) identified technology as Aclearly within the scope of issues-based geographic inquiry.≅ Projects based on GIS technology require students to identify resources, gather data, and test data in groups. The Geography Education Standards Project (1994) stated that “the power of a GIS is that it allows us to ask questions of data≅ (p. 256). This inquiry-oriented method has been highly recommended as providing lifelong skills, because it poses questions and proposes answers about the real world, which are then tested with real-world data. This study assesses the value of implementing GIS in this context.

The use of GIS technology may address the goals of school-to-career programs, helping students prepare for the future. Students use the same technology that they will encounter in the workplace. During 1999, Microsoft began marketing *MapPoint 2000* GIS software and began including a basic mapping tool with some GIS functionality in its *Excel* spreadsheet software, heralding the spread of GIS from a relatively small group of computer users and applications to a much wider audience and additional disciplines.

Authentic assessments, rather than multiple-choice tests, are increasingly required of educators. Authentic assessments include any evaluation that simulates how workers are evaluated on the job, such as an oral presentation or a portfolio highlighting work done during the semester. This study analyzes ways to practice authentic assessment for technology-based lesson modules.

Connecting GIS Implementation and Effectiveness with Education and Technology Theory

Advancements in hardware, software, operating systems, and data have made it possible to teach subject content—such as science and geography—with GIS software running on a desktop computer. The increased availability of geospatial data in computerized form has made the creation of lessons possible and affordable. Geospatial data are features and attributes linked to specific points or regions on the earth's surface, and provide the foundation for any GIS analysis. Many of these data setsXsuch as aerial photographs, satellite images, digital elevation models, hydrographic data, demographic data, transportation, and land use—are now available on the Internet. No longer confined to minicomputers and Unix or Vax workstations, GIS software is now viewed by some teachers as a superlative method and tool for science, geography, history, government, mathematics, and even language arts. But, because GIS tools and spatial data have only been accessible to many teachers for a short time, theories of curricular implementation and examples of practical application lag behind their potential application to teaching and learning.

No other technology has had as much influence on the development of the discipline of geography, and on the spread of geographic thinking into other disciplines, as GIS. A debate has arisen on the most appropriate approach to GIS instruction. Sui (1995) identified two pedagogical approaches to using the technology: Teaching *with* GIS, and teaching *about* GIS. In teaching *with* GIS, learning the software and hardware is an important by-product, but the primary goal is to aid the acquisition of concepts and content-area skills in a discipline such as geography, earth science, or history. In teaching *about* GIS, the primary goal is to teach marketable work skills by gaining practical experience with the software. This dissertation compares the two approaches as implemented by secondary teachers, and examines teaching styles, objectives, and student learning under each approach. In so doing, this study may contribute to the emergence of geographic information science as a discipline, and may aid in clarifying current debates on when GIS is used as a tool versus when GIS is best conceptualized as a science (Wright et al. 1997). It may also provide insight about the grade levels and disciplines when it is most appropriate to teach *with* GIS and when it is most appropriate to teach *about* GIS. An examination of the two approaches may provide insight to the perception of geography in secondary education and suggest ways to increase its presence in the curriculum.

One of the top ten research priorities of the University Consortium for Geographic Information Science (UCGIS 1996) is the examination of GIS on core institutional structures of society. Schools comprise one of society's largest social structures. By examining teachers' practice in schools, this research may help advance GIS in geography education from a piecemeal approach toward a nationwide geography and education research agenda. This will better enable GIS educators to influence how GIS is put to use in society.

Krygier and others (1997) advocated that geographers contribute to educational multimedia by translating literature from education and psychology into the domain of geography, providing practical examples of educational multimedia while critiquing and modifying the standards. They also advocate that geographers develop multimedia resources that help explain complex phenomena or ideas.

Exploring and evaluating how to use GIS to teach these concepts would be contribute to this goal.

In part because of education's historical neglect of geography at the secondary level, many secondary instructors are undertrained in geography. Analyzing geographic data, the process of conducting spatial analysis, means explaining how and why patterns of phenomena exist across space. Despite the fact that many geographers have been leaders in developing and using information technology in schools (Daugherty 1989), many secondary teachers are ill-trained in technology, particularly in the social studies. This clearly has negative implications for the implementation of a computer-based tool such as GIS. It is unlikely that GIS can be used effectively by a teacher who is not comfortable using a computer. Research is needed to determine if teachers are able to effectively use GIS in instruction even if they lack skills in the spatial analytical techniques and geographic concepts that underpin GIS.

To help guide administrators and teachers in future decision-making about the technology, an analysis of the extent of GIS implementation in secondary education is essential. This must include an examination of what motivates teachers to use the technology, where teachers receive their training, and the reasons and disciplines where GIS is being implemented. By addressing these questions, this dissertation addresses significant social, technological, and educational issues that affect the implementation of GIS technology in secondary instruction. By examining the disciplines in which GIS is implemented, this study assesses whether geography is benefiting from the technology, and what can be learned from the use of GIS in other disciplines. An investigation of achievement by gender will assist curriculum developers to create approaches and exercises that minimize any differences.

Perhaps the most critical limitation hampering the use of GIS in education is that few teachers are aware of GIS and its potential applications. This study analyzes how teachers become aware of GIS and how they are trained in GIS. It evaluates the effect that awareness and training have on the implementation of these technologies and methods. This study proposes ways to maximize the effect of training on teaching and learning.

A significant portion of educational GIS research funds are directed toward developing GIS interfaces that are "user friendly," in an effort to widen the technology=s appeal and to shorten its learning curve. These include two strands of research and development: (1) The creation of new packages specifically for education, and (2) the modification of the interface of commercial GIS packages. This study informs education technology research by comparing the effectiveness and implementation of such material to the use of commercial GIS packages.

Accounts of the use of GIS in high school classrooms (Friebertshauser 1997; McGarigle 1999a; Sarnoff 1999) are typically anecdotal in nature, lacking rigorous assessment. The descriptive but disconnected nature of these accounts raises concern that GIS technology and methods are being implemented independently from pedagogical theory. This could fragment GIS implementation and disconnect it from content standards and curricular goals, reducing its potential effectiveness. Research is needed to connect these ties and focus on a consistent, national set of goals.

Teachers and administrators need evidence showing that GIS is not simply another promised technical solution whose rewards will never materialize. "The benefits of adopting this technology can not be merely assumed to exist; they must be proven" (Audet 1993: 38). This dissertation seeks to provide both a quantitative and qualitative analysis of the effectiveness of GIS in teaching and learning.

Wegener and Masser (1996) caution against examining the diffusion of any technology with a pro-technology bias. This dissertation on GIS in education uses an objective approach that seeks to inform educational theory and contribute to effective educational technology by employing multiple methodologies and scales. It examines technical, administrative, and social implementation issues, student-teacher-learning relationships, acquisition of content and skills, and the social organization of the classroom. This type of analysis is advocated both by educational researchers who use GIS (such as Bednarz 1995), and those who do not (Scott, Cole, and Engel 1992). Through this interdisciplinary, multi-scale approach, the study attempts to contribute to both social science and physical science education.

Summary

This dissertation attempts to move secondary geography education with GIS from a piecemeal approach toward a nationwide research agenda. It develops a taxonomy of methods and degrees of implementation in order to analyze technological, methodological, instructional, sociological, and behavioral barriers and catalysts. It seeks to spur technology-based curriculum development, provide guidance to educators considering implementing a GIS, and steer software developers to reduce technological barriers to adoption. This research seeks to provide some of the first systematic evidence about the effectiveness of GIS in education. It examines connections between educational reform and educational technology, seeking to examine the cause-and-effect relationships between them. In so doing, it aims to further advance both geography's reputation and practice.

Society stands to benefit through *more* geography education and *better* geography education. GIS should not be a part of these improvements just because the technology has arrived on desktop computers. Rather, GIS should be considered if educators can offer students a higher-quality education through its implementation.

A lack of research on the effectiveness of geographic technology identified in a 1967 National Council for Geographic Education study is still the case more than 30 years after its publication:

> "Newer media, such as the overhead projector and the film cartridge, also have been seized upon by geographers as effective tools in geographic education. Yet the research-oriented geographer and educator have paid scant attention to assessing the effectiveness of one tool over another" (Gross 1967).

The organizers of the first conference on educational GIS asked: AWhat is the learning that GIS allows that other ways do not?≅ (Salinger 1994). Nothing less than a full answer to the question will suffice.

Having introduced the need for research in the implementation and effectiveness of GIS in secondary education, a review of the literature in geographic, educational, and instructional technology theory and development is the focus of the next chapter.